National Transportation Safety Board
Office of Aviation Safety
Washington, DC 20594

DCA22FA132

SYSTEMS AND STRUCTURES – FACTUAL REPORT

Group Chair's Factual Report

May 12, 2023

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A. ACCIDENT

Location: Miami, FL
Date: June 21, 2022
Time: 1738 EDT
Airplane: McDonnell Douglas MD-82

B. GROUP

Group Chair	Steve Magladry NTSB Washington, District of Columbia
Group Member	Dan Marcotte Boeing Long Beach, CA
Group Member	Nate Williams Boeing Everett, WA
Group Member	Steve Haggerty Boeing Long Beach, CA

C. SUMMARY

On June 21, 2022, about 1738 local time, RED Air flight 203, a Boeing MD-82, HI-1064, experienced a left main landing gear failure shortly after landing on runway 09 at Miami International Airport (MIA), Miami, Florida. The airplane departed runway 09 and came to a stop in the grassy area between runway 09 and 30. A post-crash fire occurred and was extinguished by Miami-Dade Fire Rescue (MDFR). The airplane was evacuated, and 4 passengers received minor injuries. The flight was a 14 Code of Federal Regulations Part 129 scheduled international passenger flight from Santa Domingo, Dominican Republic (SDQ) to MIA.

The #1 and #2 wheels were removed during the initial on-scene phase and the tires were removed from the wheels at a facility in Miami, FL. The tires were shipped to the Goodyear facility in Stockbridge, GA. The left landing gear was removed and shipped to the Boeing facility in Huntington Beach, CA. The landing gear and shimmy damper were examined July 19-21, and 27-28. The tires were examined August 18-19. The brake hydraulic restrictors and shimmy damper check valve were examined at the Crissair facility in Valencia, CA on September 20. The antiskid

components were removed from the airplane and examined at the Crane facility in Burbank, CA September 21-22. The following summarizes those activities.

D. DETAILS OF THE INVESTIGATION

1.0 Accident Overview (Figure 1)

From video evidence, the airplane touched down on runway 9 with approximately 8900 feet remaining. Tire deposits on the runway, which started about 1300 ft later, showed evidence of left main gear shimmy. The amplitude of the shimmy steadily increased until the left main landing gear collapsed under the airplane about 675 feet later. The airplane continued down the runway skidding on the left wing. The airplane veered left and impacted an FAA glideslope equipment building and antenna (Figure 2). Both the nose gear and right main gear then collapsed, and the airplane came to a stop.

Figure 1 Runway 9 overview

Figure 2 Final position of airplane

1.1 Tire Marks on the Runway

Figures 3 – 7 show how the rubber deposits on the runway for the left main gear tires started with a small oscillation and grew in amplitude (increasing shimmy). The labels with distance indicate approximate distance of runway 9 remaining. The tire marks changed in appearance. The initial markings were continuous and consistent with side-to-side oscillations (Figures 3 through 6). Figure 6 shows the location of the first debris found on the runway (approximately 7060 ft of runway remaining). The debris was a small piece of rubber, later determined to be from the outboard side of the #2 tire. The markings then were more arched and non-continuous, consistent with the axle/wheels turning about the vertical axis (Figure 7). The markings then changed from a two-tire pattern to a single tire pattern, and to the opposite side of the runway centerline, consistent with the tire sidewall contacting the runway after the left main landing gear collapse (Figure 8).

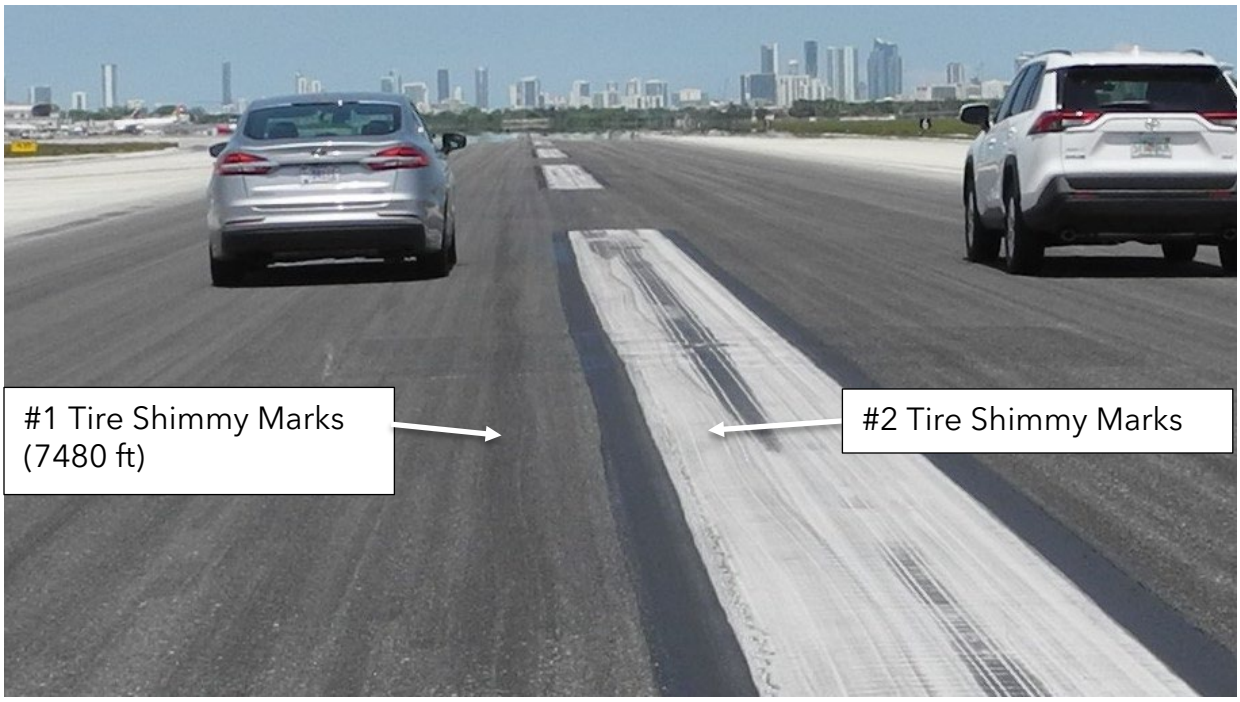

Figure 3 Start of left main gear shimmy marks

Figure 4 Shimmy marks continue

Figure 5 Shimmy marks continue

Figure 6 Shimmy marks continue

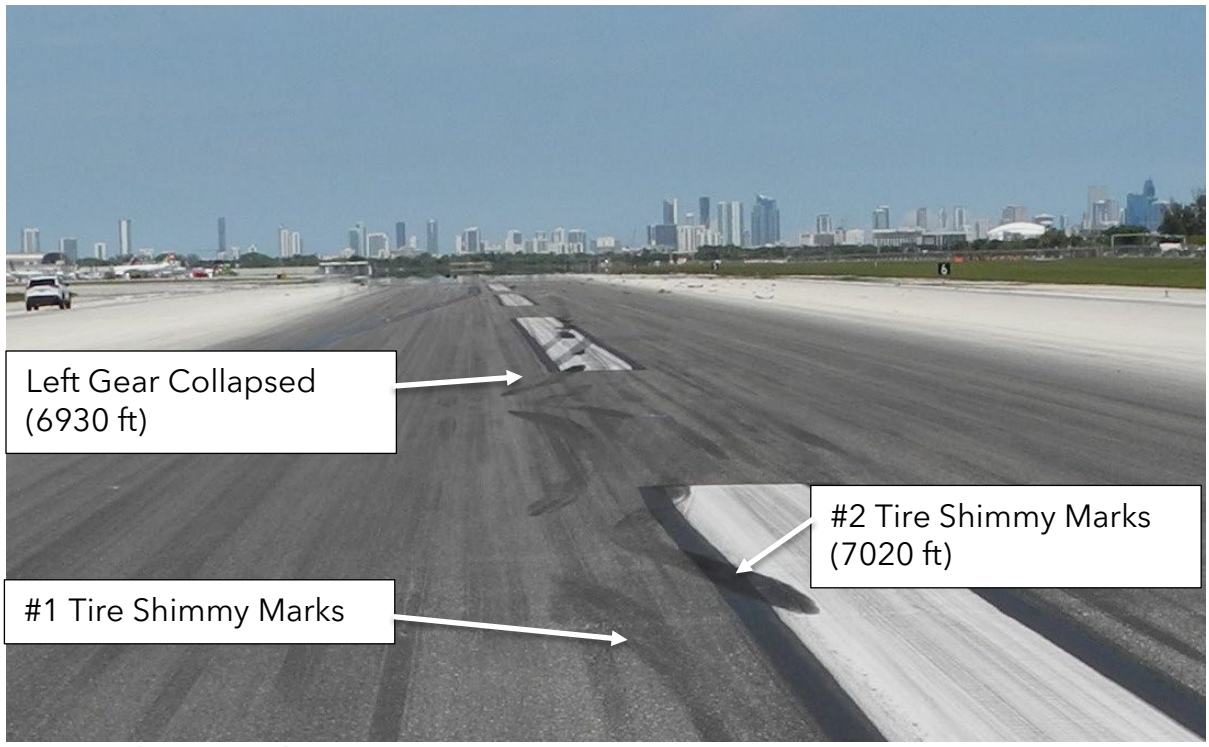

Figure 7 Shimmy marks continue

Figure 8 Tire marks after gear collapse

2.0 Main Landing Gear

2.1 Left Main Landing Gear

The landing gear components with the location of fractures are shown in Figure 9. Landing gear torque links and shimmy damper installation are shown in Figure 10. When the airplane was lifted during recovery, the gear extended, and the axle was found to be rotated outboard 90 degrees (#2 tire forward, Figure 11). The gear part number was 5935355-501, serial number CPT0718.

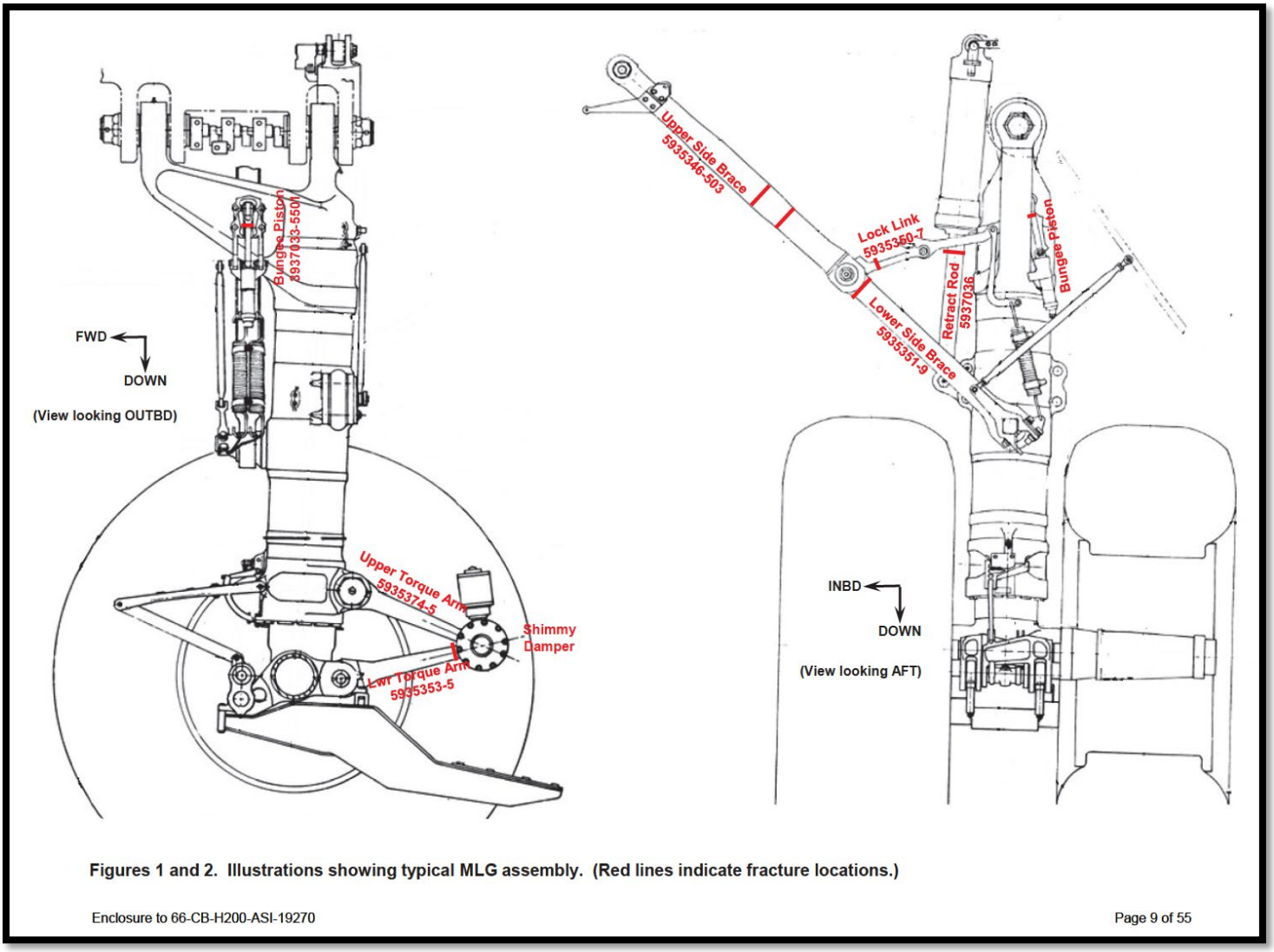

Figure 9 Landing gear components with fractures identified. Image copyright © Boeing. Reproduced with Permission.

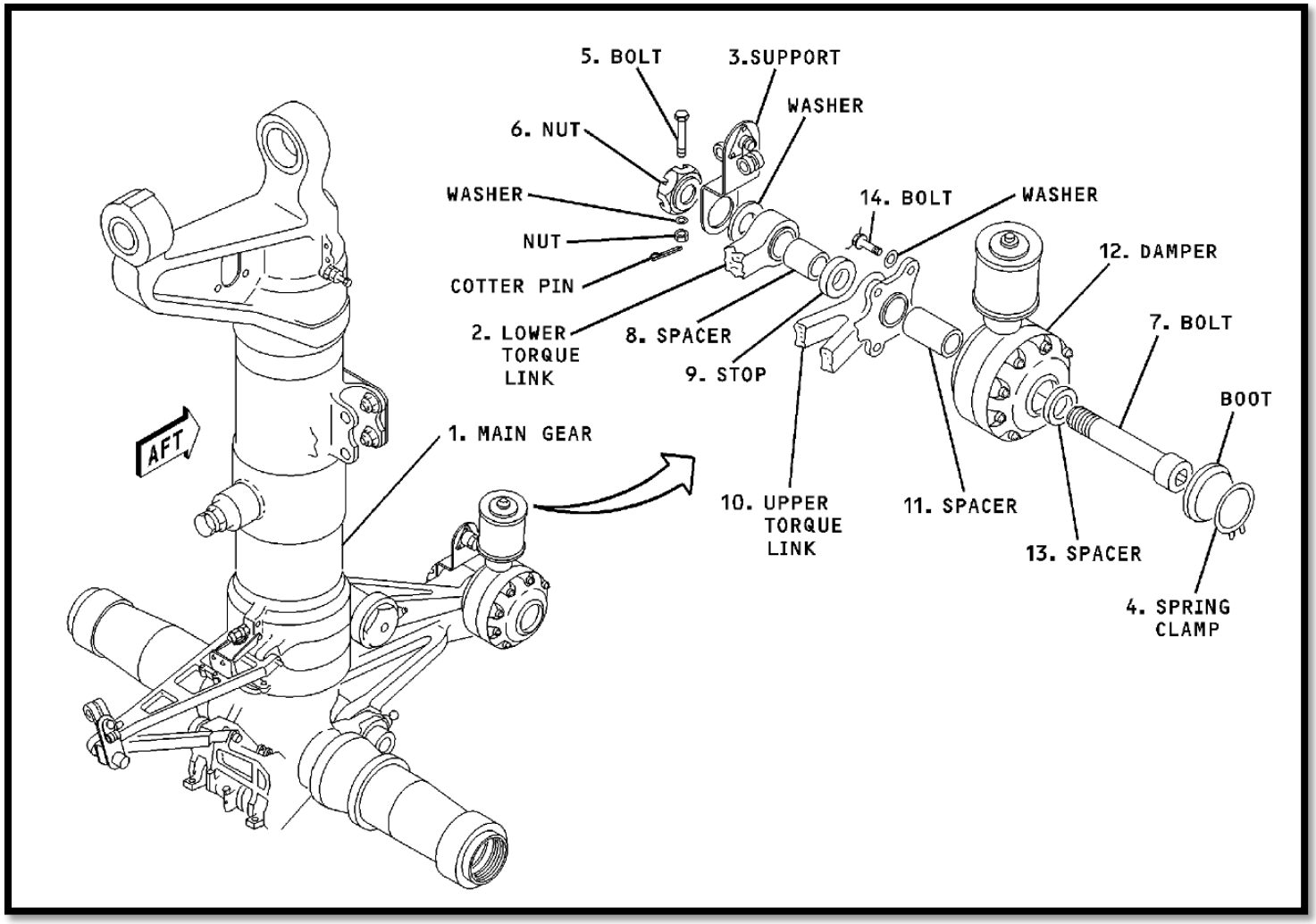

Figure 10 Landing gear torque links and shimmy damper installation. Image Copyright © Boeing. Reproduced with Permission. Note: illustration has been altered for clarity from original source.

The lower side brace fractured just below the joint of the upper and lower braces, Figure 11. The lower end of the lower side brace remained attached to the outer cylinder.

The upper side brace fractured into three pieces (to be referred to as the upper, middle, and lower). The largest piece (upper) remained attached to the airplane, Figure 12-13. The two smaller pieces, middle and lower, were recovered in the debris field just past the FAA glideslope building base, Figure 14. The middle piece had evidence of impact damage on its forward face. The damage measured approximately ½ inch in width. The lower piece included the joint and a portion of the lower side brace. A small piece of black rubber, consistent with tire material, was wedged in the joint.

The upper torque link was intact, Figure 12. The lower torque link remained attached to the inner cylinder, but the upper end fractured fully at the lug, Figure 15.

The mating structure from the lower torque link lug remained attached to the item 7 bolt (apex bolt, Figure 10).

The main landing gear retract actuator piston was fractured and bent near the fully extended position, Figure 16. The down lock actuator and upper lock link springs exhibited no damage and appeared normal. The lower lock fractured just inboard of its attachment to the upper side brace and remained attached to the side brace.

The landing gear and upper side brace were removed and shipped to Boeing for further examination. The lower and middle sections of the upper brace were shipped to the NTSB laboratory for further examination.

Figure 11 Left main landing gear (looking aft)

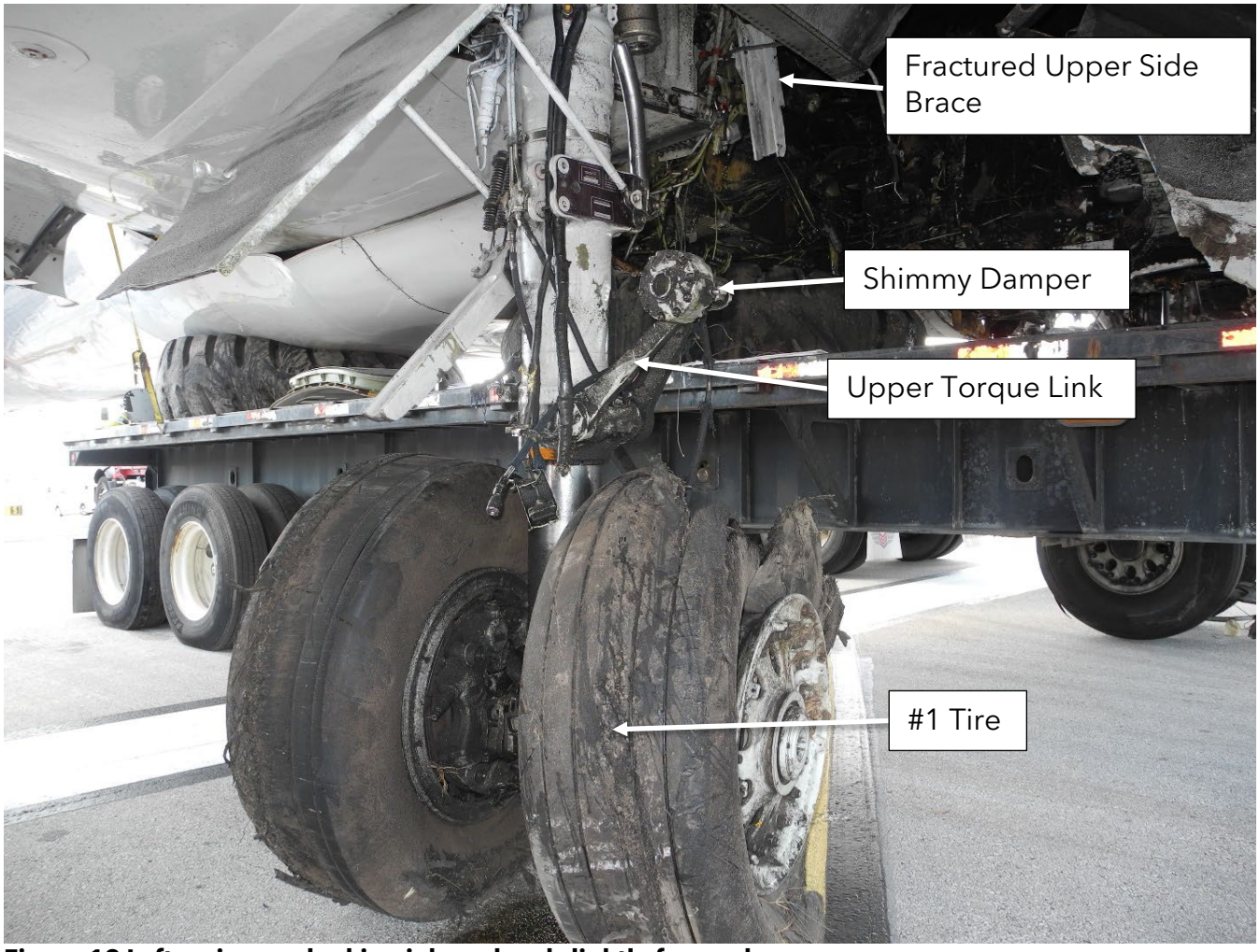

Figure 12 Left main gear looking inboard and slightly forward

Figure 13 Upper portion of upper side brace

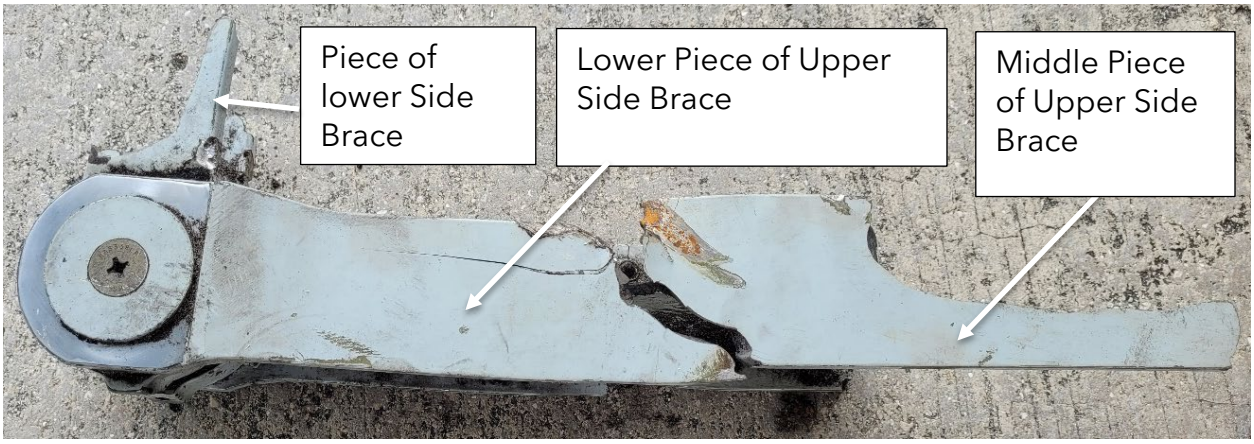

Figure 14 Left main gear upper and lower side brace pieces found after the glideslope installation

Figure 15 Left main gear looking outboard

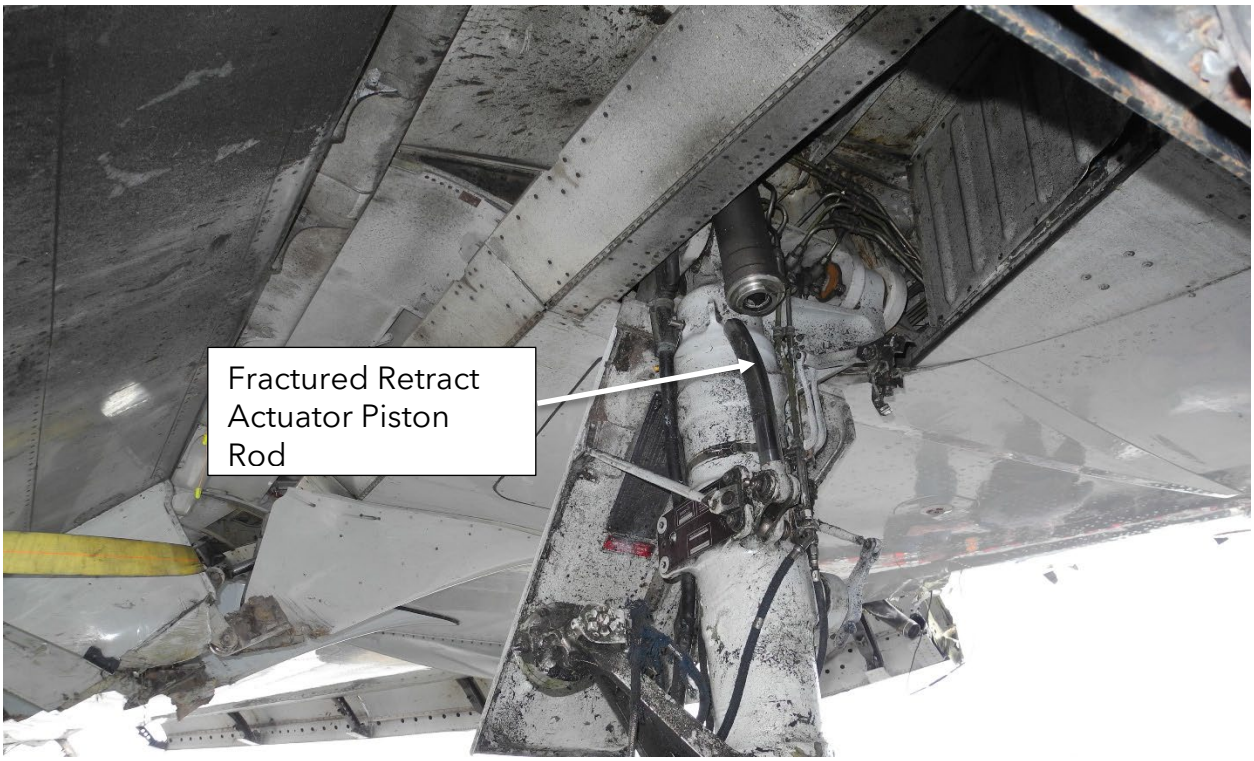

Figure 16 Left main gear retract actuator

2.1.1 Left landing Gear Examination

Between July 19 – 21, and 27-28 the landing gear components were examined at the Boeing facility in Huntington Beach, CA. The details of the examination are provided in "Attachment 1 to the Systems and Structures Factual Report" in the public docket. In summary, all fractures in the side braces and torque links occurred due to ductile separation, consistent with overload, with no evidence of fatigue failure. As part of the lab examinations, the portions of the side braces, lock links, and the left main gear were laid out in the normal configuration. The damage on the forward side of the side brace (Figure 14) aligned with damage on the outer cylinder, near the gland nut. Thus, there was indication that the side braces folded in the opposite direction than normal (hyperextended). The lower lock link was bent and sheared, with the bend being in the aft direction when normal. There was a small segment of the lower lock link, approximately 3/16 inch, missing. The upper lock link was bent with the bend being in the forward direction when normal. There was also corresponding contact marks on the upper lock link and outer cylinder.

2.1.2 Shimmy Damper

Description

To prevent excessive vibration or shimmy buildup in the main landing gear during high-speed taxi and under heavy braking, the MD-80 (like most large

airplanes with single-axle main landing gears) has a shimmy damper, Figure 17. Shimmy is a torsional vibration mode of the landing gear where the inner cylinder rotates (oscillates) relative to the outer cylinder. The shimmy damper is connected between the upper and lower torque links and allows a small, but highly damped, motion to occur around the torsional axis of the gear. Due to the geometry of the torque links, the damper effectiveness is maximized when the landing gear strut is compressed. Limited dampening capability is available when the landing gear strut it is fully extended.

The shimmy damper is a self-contained hydraulic unit consisting of a housing and hydraulic reservoir. The damper is an independently serviced, closed system that is separate from the airplane main hydraulic systems.

The damper housing contains a piston, which separates two chambers that must be filled with hydraulic fluid for proper operation. As the piston moves back and forth between the chambers, the motion is dampened by restricting hydraulic fluid flow between the chambers through orifices in the piston. The damper also employs a Belleville spring arrangement, to keep the piston centered in the damper.

A hydraulic fluid reservoir is attached to the damper housing. The reservoir contains a spring which pressurizes the hydraulic fluid in the reservoir and damper to 40 to 55 PSI. There is a bleed port at the top of the reservoir. A check valve and cap is located at the bottom of the damper housing. The damper may be serviced by adding fluid using either the bleed port at the top or the check valve on the bottom, and air is removed from the damper via the bleed port. Markings on the reservoir indicate the hydraulic fluid level in the reservoir and a label on the side of the reservoir provides servicing instructions.

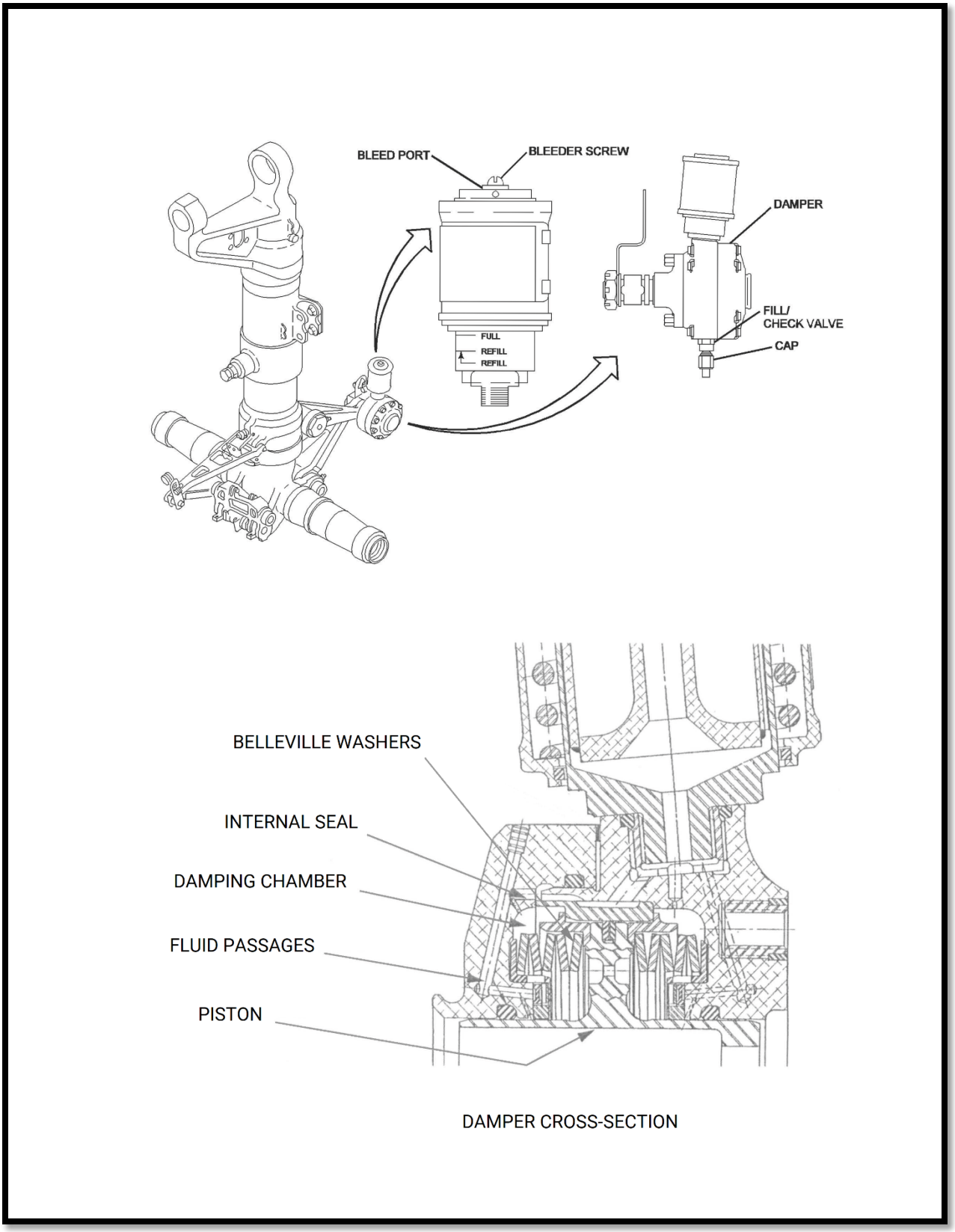

Figure 17 Shimmy damper details. Image Copyright © Boeing. Reproduced with Permission.

Condition of accident airplane shimmy damper

On June 24th, after the airplane was lifted and placed on a trailer, it was observed that the shimmy damper was missing its service port cap and hydraulic reservoir (Figures 18-19). During a search of the runway area on June 25th, the reservoir pieces, Figure 20, were found in the recently mowed grass about 200 ft north of runway 9 centerline and 6340 feet remaining on the runway. The reservoir was in many pieces and appeared to have damage consistent with impact from mower blades. The area where the reservoir is threaded into the damper housing had a large impact mark which deformed the area, and the threads were stripped.

The shimmy damper was removed from the upper torque link and disassembled at the Boeing facility in Huntington Beach, CA during the left landing gear examination July 19-21. The Part Number SR09320057-7009, S/N DL84 was etched on the nameplate and DAM5705 SR09320057-7009, S/N DL84 was etched on the housing. From the part number the following service bulletins had been incorporated in the shimmy damper:

SB-MD-80-32A275
SB-DC9-32-311
MD80-32-278

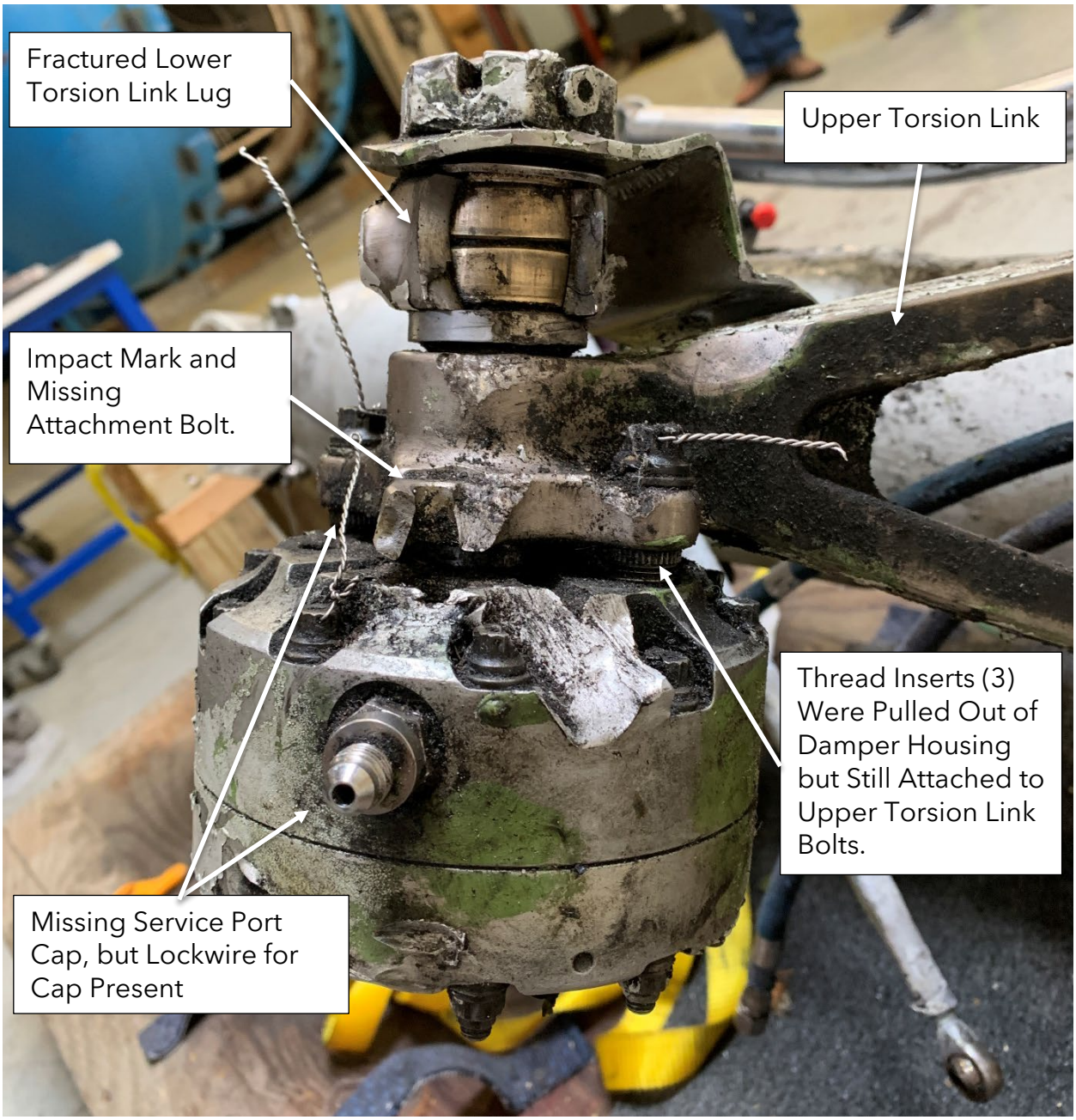

Figure 18 Left gear shimmy damper

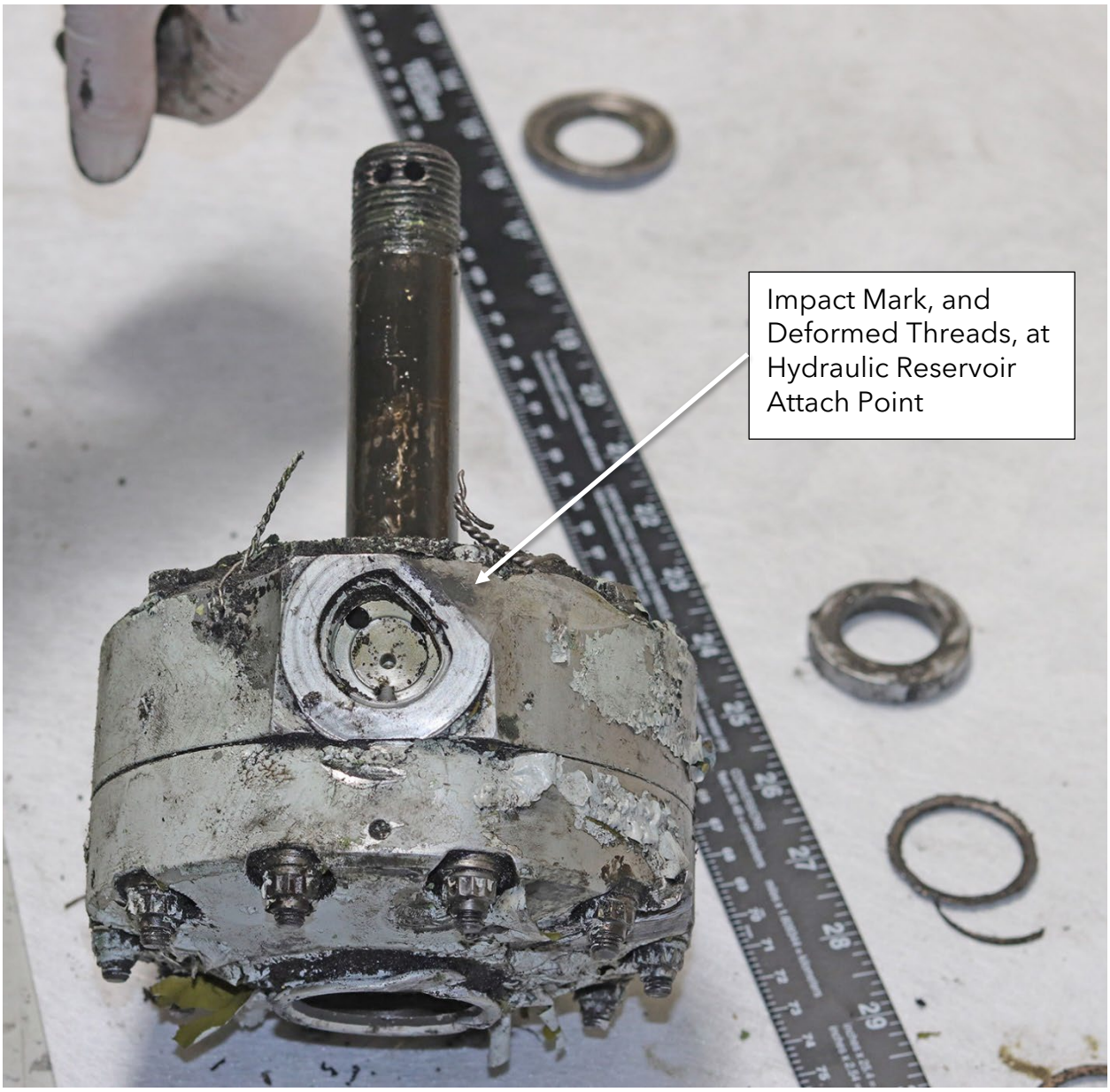

Figure 19 Shimmy damper reservoir attach point

Figure 20 Shimmy damper hydraulic reservoir pieces

There was impact damage to the cap and housing and to many of the 10 housing bolts. Breakout torque was measured for each housing bolt. Each bolt was numbered clockwise, with 1 being the bolt in the 9 o'clock position, and the reservoir at 12 o'clock as viewed from the item cap side. The torques (inch-lbs) were as follows, the specified torque is 116-126 inch-lbs:

1 – 85
2 – 140
3 – 80
4 – 83
5 – 55
6 – 15
7 – 45
8 – 30
9 – 15, half of the head was missing.
10 – 30

The cap was removed, revealing the internal components. The components on the cap side of the piston were removed and all parts were installed correctly with no apparent damage. The apex bolt had to be cut and pressed out to access the internal components on the housing side of the piston. When these were removed, all parts were found to be installed correctly with no apparent damage. The only discrepancy found was that one of the five Belleville washers was found to be fractured (the one second from the piston face), Figure 21. The fracture in the washer was examined and determined to be ductile separation.

Figure 21 Shimmy damper piston and fractured Belleville washer

The orifice (diameters) in the piston head were 0.25 inch (outer recess, not through) and 0.099 inch through hole. The item cap orifices diameters were measured (in inches) clockwise from the key position:

Outer - 0.087, 0.092, 0.092, 0.087, 0.091
Inner - 0.087, 0.088, 0.088,0.088, 0.110

Smaller orifice near the 4th outer orifice was 0.03.

The passages between the inner and outer orifices were checked with pressurized air and confirmed to be open.

The check valve/servicing port was removed from the housing. There was no cap on the valve. There was lockwire on the nut for bolt 8, there was an intact loop on the end that would have been connected to the servicing port cap. Breakaway torque was 259 inch-pounds (should be 80 -100 inch-lbs).

Computed Tomography was performed on the check valve. The results are provided in the NTSB docket. The check valve was then tested at the manufacturer (Crissair). Prior to cleaning, the valve passed the 5 psig allowable leakage rate (at 1 drop/3 minutes). An additional test was performed at 50 psig, which was not in the ATP, and it was 6 drops/3 minutes. The next ATP test for allowable leakage rate was performed at 1000 psig. A leakage of 6 drops/3 minutes was measured. The allowable limit is a trace, so it failed this test. The check valve was reversed and the crack pressure was tested and passed. The valve was then flushed (cleaned). The leakage tests were performed after cleaning and all failed: 5 psig (2drops/3min), 50 psig (3.8cc/3min), 1000 psig (20cc/min).

2.1.3 Wheels and Tires

Both tires were flat and missing significant portions of the tread. The tires were Goodyear retreads:

#1 Part Number – 446K82-2, Serial Number – 82795151
#2 Part Number – 039-853, Serial Number – none visible

The wheel part numbers, and serial numbers are:

#1 2608891-1, sub-assembly 260887, SN H2052
#2 2608891-1, sub-assembly 260887, SN 2202

The #1 and #2 wheel assemblies were removed from the airplane and taken to a local company in Miami for disassembly. The wheel bolts were numbered 1-18 starting with #1 at the fill valve proceeding clockwise. The torque on each bolt was checked and all measured at least 155 in-lbs. The bolt heads on the inside of the rim were ¾ inch for wheel #1 and 11/16 inch for wheel #2. The diameter for all the bolts

was the same at 0.62 inch. According to Honeywell the ¾ inch head is an allowed optional bolt material (Inconel). The tires were removed and packaged for shipment to Goodyear.

On August 18-19 the tires were examined at the Goodyear facility in Stockbridge, GA. Overall observation of the internal liner of both tires revealed that there were no circumferential wrinkles in the shoulder areas which indicated the tires were not operated in a significantly underpressurized condition. There were numerous impact areas on each tire which could have resulted in the tires to burst. There were no flat spots or evidence of skids in the tread area. The retread packages were well adhered. There were no unusual tread wear patterns attributable to poor tire maintenance.

The first piece of debris found on the runway was able to be matched to the shoulder area on the outboard side of the #2 tire. The #2 tire showed significant skidding on the sidewall on the inboard side around the entire circumference.

2.1.4 Brakes

The brakes appeared to be undamaged except for debris present. The brake wear indicator pins were measured: #1 = ½ inch, #2 =1inch. The wear indicator is only accurate with brake pressure and brake set, but a measurement can give approximate condition. Brakes are allowed to be used until the indicator is flush with the brake housing (0 inches).

2.2 Right Main Landing Gear

The right gear collapsed and was up in the wheel well when the airplane came to rest. After the airplane was lifted, the gear dropped down to almost the down and locked position, but not quite, Figure 22. All components were intact and undamaged except for the bungee cylinder upper hydraulic tube was fractured, and the lock links position was slightly short of center. The gear part number was 5935355-501, serial number CPT1232.

Figure 22 Right main landing gear

2.2.1 Tires and Brakes

The tires were inflated (#3-191 psi, #4-190 psi), with plenty of tread remaining. The allowable tire pressure for the airplane (takeoff weight 135,634 lbs), was 162 - 200 psi. After measuring the tire pressure, they were deflated for safety. The brake wear indicators were measured: #3 = ¾ inch, and #4 = 11/16 inch, which is acceptable. There were numerous impact marks on both tires.

2.2.2 Shimmy Damper

The shimmy damper was intact and properly serviced with servicing port cap installed and properly lock wired, Figures 23-24.

Figure 23 Right gear shimmy damper with hydraulic reservoir intact

Figure 24 Right gear shimmy damper service port

3.0 Antiskid Components

3.1 #1 Wheel Speed Transducer and Wiring

The hubcap was not present, it was found on the runway. The transducer was removed from the electrical connector and retained by the NTSB (Part Number 40-62575, SN 8471). The wheel speed transducer wire harnesses were removed from the axle and retained by the NTSB. The harness was fractured approximately halfway up the strut, so no cutting was required. The #1 wire harness had a label G36F20BL, which was confirmed to be connected to the left outboard wheel speed transducer according to WDM 32-41-00, page 2 sheet 1.

3.2 #2 Wheel Speed Transducer and Wiring

The hub cap was removed to expose the wheel speed transducer. The transducer was disconnected from the electrical connector and retained by the NTSB. Part Number 40-62575, SN 8443. The #2 wire harness had a label G34F20BL, which was confirmed to be connected to the #2 wheel speed transducer according to WDM 32-41-00, page 2 sheet 1.

3.3 Antiskid Control Unit and Control Valves

The antiskid control unit was removed from the electronics rack during the initial on-scene phase. The left gear antiskid control valves were later removed and shipped to the Systems Group Chairman.

3.4 Antiskid Component Testing at Crane Aerospace

The antiskid components were re-packaged and shipped to Crane and placed in quarantine. The antiskid components were examined at the Crane facility in Burbank, CA September 21-22, 2022 with the following results:

3.4.1 Antiskid Control Unit

Part Number 42-807, Serial Number 897C, MFD 5-91. All the quality seals were intact. The unit was tested according to the ATP, there were no anomalies noted.

3.4.2 Wheel Speed Transducers

#1 wheel speed transducer - Part Number 40-62575, Serial Number 8471, MFD 06-90. It was noted that one of the coupling arms to the hubcap was loose and longer than the other, indicating it had partially backed out.

#2 wheel speed transducer - Part Number 40-62575, Serial Number 8443, MFD 06-90. It was noted that one of the coupling arms were slightly bent and both coupling arms were partially backed out.

The transducers were tested according to the ATP. Both slightly failed the 2800 RPM voltage requirement and the section 4.5 operational characteristics 525 RPM armature voltage maximum. It was noted that the frequency displayed on the oscilloscope varied considerably and didn't seem to increase linearly with an increase in RPM. This parameter was not part of the ATP tests and as such the significance was not known. Crane later performed additional testing using a frequency counter and it was concluded that there was no problem with the frequency output of the transducers.

It was noted that the lockwire did not conform to standards, which suggested that the units had been disassembled after production. There were no records of these parts been returned to Crane for servicing. It was decided to partially disassemble the Serial Number 8471 transducer. One of the internal wires (yellow) showed a dark brown deposit, but the wiring appeared to be undamaged under the deposit. Crane noted that the potting was different than production RTV. Crane reassembled the transducer.

3.4.3 Control Valves

Left Outboard Valve – Part Number 39-249-2, Serial Number 2312ABC
Left Inboard Valve - Part Number 39-249-2, Serial Number 2174ABC

There was no indication of manufacture date on the valves, but Crane records indicate the following:

S/N 2312ABC, Manufacture date was 9/24/1986
S/N 2174ABC, Manufacture date was 6/23/1986

Hydraulic fluid samples (6) were taken from the two brake ports and 1 return port for each valve. The samples were analyzed for particulate size and quantity and classified according to AS4059. The results ranged from Class 9B to 11F. These exceed the recommended fluid particulate sizes but is considered common in dead ended hydraulic systems such as the brakes.

The valves were tested according to the ATP. During initial testing of the Outboard Valve, it was found that there was no response from the valve. After troubleshooting it was found that the test stand wire harness was faulty. The test harness was bypassed and wired directly from the test stand to the valve. After this the ATP was performed. Both valves passed most of the tests except both failed to

meet the tolerances of the servo valve current versus brake pressure tests. The system affect would be slightly degraded antiskid performance. The antiskid control unit can compensate for the valve pressure differences, but there may be more or less skids when operating at peak control. The ATP results show the valves were able to achieve full brake pressure dump which would prevent a fully locked wheel condition.

4.0 Nose Landing Gear

There was substantial structural damage to the nose wheel well. The nose landing gear was folded aft with the tires lodged in the forward electronics bay. After the airplane was moved, and the airplane supported on jacks, the recovery team dislodged the nose gear and it extended.

5.0 Red Air Airplane Inspections

In November 2022, the NTSB observed the condition of Red Air airplanes shimmy dampers at Miami International Airport. Airplane HI1066 had both left and right shimmy dampers properly serviced, with service port caps installed, but both service port cap lockwires were installed incorrectly (wrong orientation), Figure 25. Airplane HI1069 both left and right shimmy dampers properly serviced, with service port caps installed, and lockwire installed correctly.

Figure 25 Red Air airplane HI1066 right main gear shimmy damper

In December a team travelled to the Dominican Republic to interview members of the Instituto Dominicano de Aviación Civil (IDAC) and Red Air maintenance personnel. On December 7th the team had an opportunity to inspect the shimmy

damper installations on Red Air airplanes at the gates. The first airplane inspected was HI1069. The shimmy dampers were near the full position and the caps were correctly installed and safety wired. It was noted and pointed out to the Red Air Director of Maintenance (DOM) that the fill level on the right gear damper could not be viewed because the lettering was worn. Measurements of the displacement of the reservoir cap were taken and compared to the left gear, and it was concluded that the reservoir was near the full level (the red line of cap was approximately 28 mm from the bottom edge of the base).

The second airplane arrived about an hour later (HI1066) and as the team arrived at the airplane there were numerous mechanics around the right main gear in the area of the shimmy damper. As we approached, it became clear that they were servicing the damper. However, they were unable to maintain pressure because the fluid would leak out of the check valve at the base of the damper when the servicing hose was loosened. The method of adding fluid was to use a hand pump connected to a can of Skydrol. When it became clear that the damper would not hold pressure, they ordered a new part to be delivered from Miami. We questioned the DOM as to why it was being serviced and they said it was a routine S check. We asked to see the logbook and the last S check was performed on Dec 4th, so that was consistent with timing of an S check every three days. The NTSB requested that the removed damper be quarantined and sent to the Systems Group Chairman for examination. There was a spool of lockwire, 0.032 inch diameter, on the ground in the area where they were servicing the damper, which is the correct size. The left gear was observed to be serviced correctly with cap and lockwire in place. However, the lockwire was not installed in the correct orientation to resist the cap from loosening. This was pointed out to Red Air maintenance inspector, and he agreed with the finding. This was pointed out to the DOM and later corrected.

The removed right shimmy damper from HI1066 was shipped to the NTSB and examined on December 20, 2022. The servicing port/check valve was found to be filled with metal shavings. It was also found that one of the Belleville washers, and the cage that retains the washers were installed incorrectly on both sides of the piston. This caused deformation and chaffing of the cage which resulted in the presence of metal shavings through the piston area.

6.0 Flight Deck Documentation

From the control stand the following was observed, Figures 26-27:

Stabilizer Trim – 8 units
Spoiler Handle – Stowed
Throttles – Aft stop
Flaps Handle – Approximately 15 units

Fuel Shutoff – Both off
Auto Brake – Off and Disarm
Rudder Trim – 1 unit nose right
Aileron Trim – 1 unit left wing down

Other items noted, not on the control stand:

Landing Gear Handle – Down position
Antiskid Switch – Arm
Right Engine Fire Handle – Pulled, but not turned.

Figure 26 Control stand

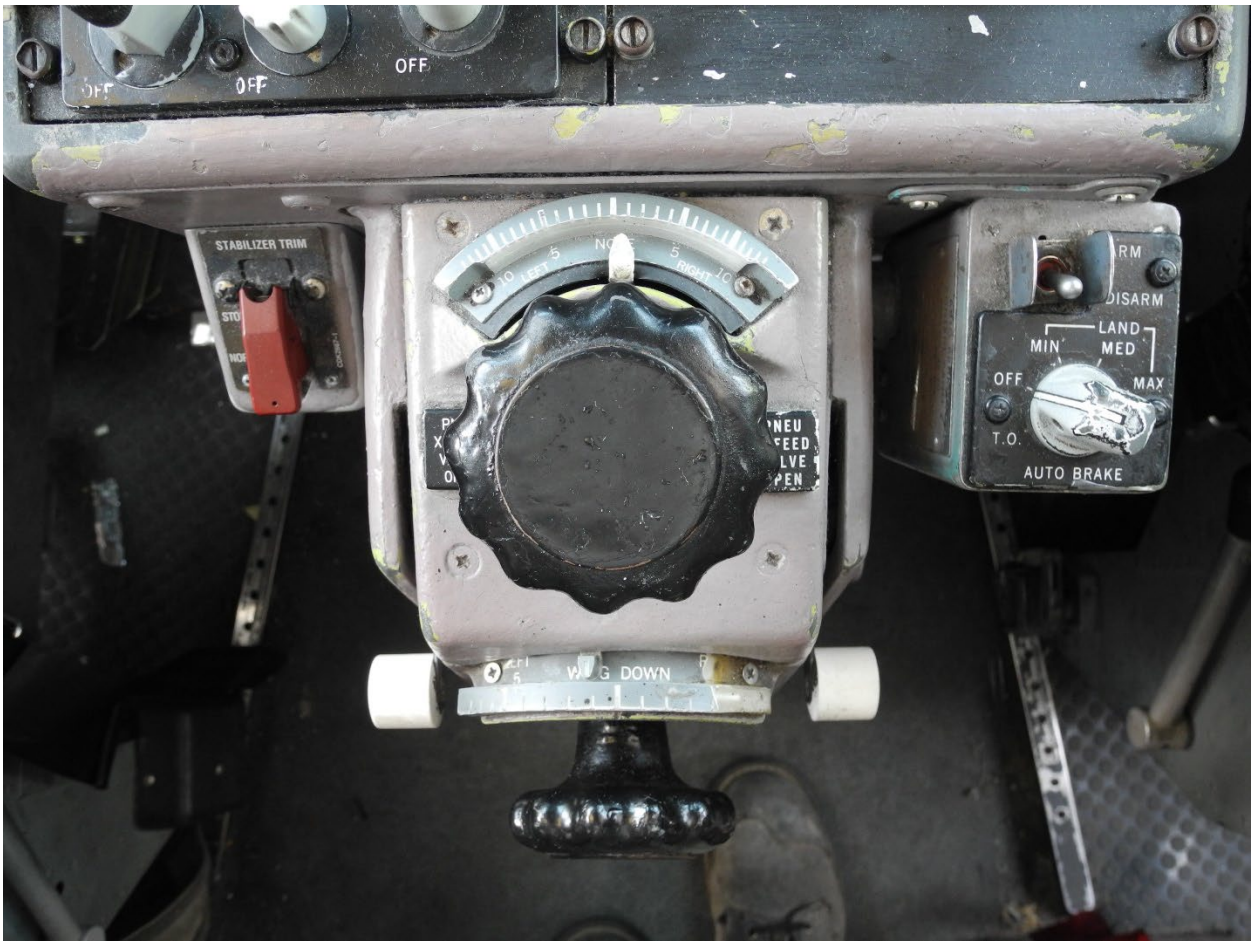

Figure 27 Aft control stand

Steven Magladry
Aircraft Systems Investigator